higher Ms magnetic layer 23. This low Ms magnetic layer 22 helps to improve writeability with respect to the conventional dual-layer SUL design. The SUL 20 of the present invention thus comprises a first magnetic layer 21 formed on top of the substrate 10, an ultra-thin Ru layer 25 formed on top of the first magnetic layer 21, a second magnetic layer 22 formed on top of the Ru layer 25, and a third magnetic layer 23 formed on top of the second magnetic layer 22 so that the Ru layer 25 is formed between the first magnetic layer 21 and the second magnetic layer 22.

The second and third magnetic layers 22, 23 are configured to have different magnetic compositions from each other. In the preferred embodiment, magnetization of the second magnetic layer 22 is lower than magnetisation of the third magnetic layer 23. However, even if magnetisation of the second magnetic layer 22 is higher than that of the third magnetic layer 23, ROW will still be improved although track-width will be wider. Preferably, the first and third magnetic layers 21, 23 each have a higher MsT (where Ms is the saturation magnetization and T is the layer thickness) than the MsT of the second magnetic layer 22. The MsT ratio of the second and third magnetic layers 22, 23 decides the exchange coupling with the first magnetic layer 21. The exchange coupling is dominantly an interfacial phenomena, therefore coupling between the first magnetic layer 21 and the second magnetic layer 22 will be a more dominant factor than between the first magnetic layer 21 and the second magnetic layer 22 and the third magnetic layer 23 together. Insertion of the second magnetic layer 22 with Co content ranging between 25 to 30% weakens the coupling between the first magnetic layer 21 and the third magnetic layer 23 which has Co content ranging between 50 to 60%. Thus, the MsT of the first magnetic layer 21 is preferably higher than a combined MsT of the second magnetic layer 22 and the third magnetic layer 23. In this way, track-width can be maintained while improving ROW. Where a ratio of MsT of the second magnetic layer 22 to MsT of the third magnetic layer 23 is between 0.66 and 1.5, an optimized ROW and track-width performance is obtained.

Preferably, the second magnetic layer 22 should have a lower Ms than the first magnetic layer 21 and the third magnetic layer 23. For a more pronounced effect, the second magnetic layer 22 should be Fe rich so as to reduce the coupling between the magnetic layers 21, 22, 23 accordingly on either side of the Ru layer 25. The MsT ratio has to maintained between the second and third magnetic layers 22, 23 to keep a balance of ROW advantage while at the

track-width (SNR) are shown in FIGS. 3 and FIGS. 4 respectively. As can be seen in FIG. 3, media with the triple-layer SUL of the present invention shows higher ROW with comparable to narrower track-width when compared with media with the conventional dual-layer SUL. ROW gain of 1dB with 1nm narrower track-width performance is observed on average. In FIG. 4, for media with the triple-layer SUL, an average gain of 0.16 dB SNR is observed when compared to the media having a dual layer SUL structure. Overall, by providing a triple-layer of SUL in an otherwise conventional perpendicular recording medium, areal density gain can be achieved.

Whilst there has been described in the foregoing description preferred embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations in details of design, construction and/or operation may be made without departing from the present invention. For example, while it has been described above that the Ru layer is formed between the first magnetic layer and the second magnetic layer, the Ru layer may alternatively be formed between the second magnetic layer and the third magnetic layer to achieve similar improved ROW while maintaining track-width.

Claims

1. A perpendicular recording medium comprising:

a substrate;

a soft underlayer comprising a first magnetic layer formed on top of the substrate, a second magnetic layer formed on top of the first magnetic layer, a third magnetic layer formed on top of the second magnetic layer, and a Ru layer formed between one of: the first magnetic layer and the second magnetic layer, and, the second magnetic layer and the third magnetic layer;

an orientation control layer formed on top of the soft underlayer;

an intermediate layer formed on top of the orientation control layer; and

a recording layer formed on top of the intermediate layer,

wherein magnetisation of the second magnetic layer is lower than magnetisation of the third magnetic layer.

2. The perpendicular recording medium of claim 1, wherein MsT of the first magnetic layer and MsT of the third magnetic layer are each higher than MsT of the second magnetic layer.

3. The perpendicular recording medium of any preceding claim, wherein MsT of the first magnetic layer is higher than a combined MsT of the second magnetic layer and the third magnetic layer.

4. The perpendicular recording medium of any preceding claim, wherein cobalt content of the first magnetic layer is higher than cobalt content of the second magnetic layer.

5. The perpendicular recording medium of any preceding claim, wherein iron content of the second magnetic layer is higher than iron content of the third magnetic layer.

6. The perpendicular recording medium of any preceding claim, wherein iron content of the second magnetic layer is higher than iron content of the first magnetic layer.

7. The perpendicular recording medium of any preceding claim, wherein the third magnetic layer comprises a high magnetization CoFe-based alloy with Co content

ranging between 50 to 60% and Fe content ranging between 15 to 20% and wherein the second magnetic layer comprises a CoFe- based alloy with Co content ranging between 25 to 30% and Fe content ranging between 50 to 55%.

8. The perpendicular recording medium of any preceding claim, wherein the first magnetic layer comprises a high magnetization CoFe-based alloy with Co content ranging between 50 to 60% and Fe content ranging between 15 to 20%.

9. The perpendicular recording medium of any preceding claim, wherein ratio of MsT of the second magnetic layer to MsT of the third magnetic layer is between 0.66 and 1.5.